Land Tenure and the Adoption of Conservation Practices

Meredith J. Soule, Abebayehu Tegene, and Keith D. Wiebe

We use a logit adoption model with data on 941 U.S. corn producers from the 1996 Agricultural Resource Management Study to analyze the influence of land tenure on the adoption of conservation practices. We extend previous analyses by distinguishing renters according to lease type and by distinguishing practices according to the timing of costs and returns. We find that cash-renters are less likely than owner-operators to use conservation tillage, but share-renters are not. Both cash-renters and share-renters are less likely than owner-operators to adopt practices that provide benefits only over the longer term (grassed waterways, stripcropping, and contour farming).

Key words: Adoption, corn production, soil conservation practices, land tenure.

Introduction

Does land tenure affect a farmer's adoption of conservation practices? This is a classic question in economics. In the wake of the Dust Bowl, Ely and Wehrwein argued that "[i]f the American farm owner's 'conservation relationship' to his farm is weak, it is practically non-existent in the case of tenants" (p. 218), since tenure insecurity gives renters little incentive to maintain soil fertility or control erosion. The question remains important today. Agricultural Census data show that leasing declined from 45% of U.S. farmland in 1935 to 35% in 1950, but subsequently increased to 41% by 1997. Leasing is even more important in the Corn Belt, where in 1997 about half of all acres were leased. Decisions by renters thus have implications for overall adoption of conservation practices in the U.S. If renters are indeed less likely than owner-operators to use conservation practices, programs to encourage the use of conservation practices may need to consider renters' and landowners' incentives more explicitly.

The conventional hypothesis that owner-operators are more likely than renters to adopt conservation practices is easily tested with appropriate data and models, and has been explored by an extensive body of research. However, research to date has provided inconclusive or contradictory results, because it has not adequately addressed two important dimensions of the relationship between tenure and conservation. First, tenure's impact may depend on the timing and magnitude of the costs and returns generated by the conservation practice under study. For example, conservation tillage may increase short-term profits due to cost savings, while it may take several years to generate positive net returns to "medium-term practices" such as contour farming, stripcropping, or grassed waterways. Tenure's role in adoption is likely to vary with these differences.

Secondly, different lease arrangements may also influence renters' conservation decisions. For example, share-renters may have an additional incentive, relative to cash-renters, to adopt conservation practices that increase use of inputs for which they bear only a share of the cost. Furthermore, landlords tend to participate more actively in the management of farms rented under share leases (Rogers). This could induce share-renters to behave more like owner-operators than cash-renters. Failure to consider such distinctions would obscure tenure's true effect on the adoption of conservation practices.

This paper explores these two dimensions both conceptually and empirically using new data on corn production from the 1996 Agricultural Resource Management Study

---

Meredith J. Soule, Keith D. Wiebe and Abebayehu Tegene are economists in the Resource Economics Division of USDA's Economic Research Service. Senior authorship is shared. The helpful comments of Roger Claassen, Ralph Heimlich, Robbin Shoemaker, Gene Wunderlich, and two anonymous reviewers, as well as the GIS support provided by Vince Breneman and the SAS assistance of Bill McBride, are gratefully acknowledged. The views expressed in this paper are those of the authors, and may not be attributed to the Economic Research Service.

(ARMS) survey, which covers sixteen states that account for about 90% of corn farms, acres, and bushels harvested in the U.S.[1]

Previous Research

Farmers consider a variety of factors in deciding whether or not to adopt particular conservation practices. Non-economic factors play a role, such as awareness of local water quality problems or attitudes toward the environment (Ervin and Ervin; Lynne, Shonkwiler and Rola). Economic factors, including both short-term profitability and long-term asset value, are also important (McConnell; Bills; Miranowski and Cochran). Following the conventional wisdom as articulated by Ely and Wehrwein, renters would be expected to be concerned about the short-term profitability of land they rent, but less so about its long-term value. By contrast, owner-operators would be expected to care about both short-term profitability and the long-term value of their land. We would thus expect to see tenure-related differences in adoption of different conservation practices, depending on how those practices affect short-term profitability, long-term value, or both.

A wide variety of activities may be considered conservation practices because they maintain or improve soil fertility, or reduce soil erosion and runoff of nutrients and pesticides. These include residue management practices (e.g., conservation tillage), soil-conserving crop rotations, nutrient and pest management practices, and land improvements (e.g., installation of grassed waterways). These practices differ from one another and from conventional management practices in the expected magnitude and timing of their costs and returns to the farmer. Some practices, such as conservation tillage, may be profitable in the short term due to reduced labor and machinery costs (Klemme; Rahm and Huffman). Others may become profitable only over the medium term (e.g., contour farming, stripcropping, and grassed waterways) or the long term (e.g., terracing) as they control erosion and maintain or enhance soil fertility and thus improve productivity and land values. Day, *et al.* calculated net returns to conservation and conventional tillage under corn production in ten Corn Belt states using 1996 data. Average net returns per acre under conservation tillage ranged from $168 to $251. Under conventional tillage, net returns ranged from $127 to $246. They concluded that net returns with conservation tillage generally equal or exceed net returns with conventional tillage, while variable costs are the same or lower with conservation tillage. According to Farm Service Agency records, annualized costs for grassed waterways, stripcropping and contour farming averaged $15, $6 and $1 per acre, respectively, for the sixteen states in this study in 1996. Some farmers may have received federal cost-shares of up to 80%.

Tenure has been conceptualized in many ways in research on the adoption of conservation practices. Most studies have sampled farm operators, using the proportion of farm acres that are rented to indicate tenure status (Rahm and Huffman; Belknap and Saupe; Norris and Batie; Featherstone and Goodwin). Others have used dummy variables to identify operators as full-owners, owner-renters or full-renters (Lynne, Shonkwiler and Rola), or to identify fields as owner-operated or not (Fuglie and Bosch). Alternatively, a few studies have sampled landlords (Lee; Lee and Stewart; Heimlich), using dummy variables to distinguish full-owner operators, part-owner operators, and non-operator landlords. Little attempt has been made to differentiate between cash-renters and share-renters, although share leases represent 30% of all farmland lease contracts and area in the U.S., and around 40% in the Corn Belt (Rogers). This neglect may be significant since share-renters, with more active landlord participation in farm decisions, may be more likely than cash-renters to adopt conservation practices (Esseks and Kraft).

Most empirical research on the relationship between tenure and conservation practices has focused on the adoption of some form of conservation tillage or crop residue management. Several studies support conventional expectations that owner-operators are more likely than renters to adopt conservation tillage (e.g., Lynne, Shonkwiler and Rola using Florida data; Belknap and Saupe using Wisconsin data; and Ribaudo and Shoemaker using national data). However, a second group of studies found no significant relationship between tenure and adoption of conservation tillage (e.g., Rahm and

[1] The states are Kansas, Nebraska, South Dakota, and Texas (Plains); Michigan, Minnesota, Pennsylvania, and Wisconsin (North Central); Illinois, Indiana, Iowa, Missouri, and Ohio (Corn Belt); North Carolina, South Carolina and Kentucky (East).

Huffman using Iowa data; Norris and Batie using Virginia data; and Fuglie and Klotz using data from Pennsylvania and Maryland). Lee did not examine conservation tillage directly, but found no significant differences in soil erosion rates between tenure groups at the national level. Also using national-level data, Bills found that rented land erodes more rapidly than owner-operated land, but attributed this to the greater proportion of rented land in erosive row crops rather than to inferior conservation practices. Finally, Hinman, Mohasci and Young found that conservation tillage became profitable sooner for renters than for owner-operators in Washington and Idaho, apparently because share-renters realized a higher share of the cost savings than they bore of the yield reductions.[2]

Less research has been done on medium or long-term conservation practices, such as crop rotations, stripcropping, grassed waterways, contour farming, or investments in soil conservation structures such as terraces. Such investments are expected to produce long-term benefits but they may also involve significant short-term costs. Conventional wisdom thus holds that the adoption of medium and long-term conservation practices will be closely associated with land ownership. In studies examining such practices, the dependent variable has often been defined as either the number of practices used (Ervin and Ervin; Lynne, Shonkwiler and Rola) or as expenditures on conservation investments (Norris and Batie; Nielsen, Miranowski and Morehart; Featherstone and Goodwin; Young and Shortle). Tenure was found to be significant in four of these six studies. Ownership of the land was found to have a positive impact on conservation investment expenditures and a negative impact on the number of conservation practices used.

Conceptual Framework

We extend these earlier analyses by developing a simple two-period model based on McConnell. Assume that farmers choose a production practice i (and associated input levels) to maximize the present value (PV) of current net returns plus terminal land value:

$$\max_{(i)} PV_i = \pi_i + V_i/(1+r), \tag{1}$$

where $\pi_i =$ current net returns under practice i, $V_i =$ terminal land value (itself a function of expected future net returns) given practice i in the first period, and $r =$ the discount rate. We designate $i = t$ for a traditional production practice and $i = c$ for a conservation practice, where the conservation practice reduces soil erosion relative to the traditional practice, maintains or improves land productivity over time, and better preserves the long-term value of the land. Thus $V_c > V_t$. Farmers select the optimal practice by choosing i to maximize equation (1).

Although risk is one possible explanation for the use of share-leases (Cheung; Stiglitz), a share-lease may be more efficient than a cash-lease even under conditions of certainty (Robison and Barry). Our goal is not to explain choice of lease-type but rather to examine technology choice, given the choice of lease. However, we recognize that the renter may not have a choice in the technology if the landowner stipulates in the lease contract that the renter must use a particular practice. In that case, the renter does not choose the production practice directly, but rather chooses to accept or reject the lease contract. All observed renters have chosen to accept the contract, and we assume that they have done so because they can farm profitably, given the conditions of the contract.

The conventional hypothesis that owner-operators are more likely than renters to adopt conservation practices can be explored by weighting the second term on the right-hand side of equation (1) by a tenure-security indicator γ, which represents the farmer's subjective belief that he will be able to use or sell the land in the second period:

$$\max_{(i)} PV_i = \pi_i + \gamma V_i/(1+r). \tag{2}$$

Empirical data on the value of γ is scarce.[3] Given the lack of data, it is reasonable to assume that $\gamma = 1$ for owner-operators. Ely

[2] Lee and Stewart reported that full-owner operators were less likely to adopt minimum tillage or residue management practices than were part-owner operators or non-operator landlords. Heimlich countered that both minimum tillage *and* residue management are necessary to improve soil conservation; repeating Lee and Stewart's analysis accordingly, he found no difference by tenure.

[3] Information on terms of lease contracts and variables that impact the level of γ for renters, such as length of lease and the number of years a renter has been leasing the field, would be very useful but was not available for this study. Future surveys on the adoption of conservation practices would be enhanced if such questions were incorporated.

and Wehrwein might argue that γ is near zero for renters, but it is sufficient to assume that $0 \leq \gamma_{\text{renter}} < \gamma_{\text{owner-operator}}$. For example, we can think of γ_{renter} as being closer to 1 the stronger is the renter's belief that the lease will continue beyond the first period. Thus, γ_{renter} would depend on the expected duration of the lease. It is optimal for a risk-neutral farmer to adopt the conservation practice when

$$(3) \quad \pi_c + \gamma V_c/(1+r) > \pi_t + \gamma V_t/(1+r),$$
$$\text{i.e., when} \quad \pi_c > \pi_t - \gamma(\Delta V),$$

where $\Delta V = (V_c - V_t)/(1+r)$. Since $\Delta V > 0$ and $\gamma_{\text{renter}} < \gamma_{\text{owner-operator}}$, the threshold level of π_c is lower for owner-operators than for renters, as reflected in the conventional hypothesis.

Substituting the relevant values of γ for owner-operators and renters into condition (3) yields the criteria for adoption of a given conservation practice. If the conservation practice offers short-term gains relative to the traditional practice (as is the case for conservation tillage under certain circumstances), the value of γ is irrelevant and both owner-operators and renters will adopt the conservation practice. If the conservation practice involves short-term losses that are exceeded by gains in the present value of future net returns (as is the case for medium or long-term practices under certain conditions), owner-operators and some renters will adopt it. If short-term losses exceed long-term gains, the value of γ is again irrelevant and no farmer will adopt the conservation practice. Thus we see that the hypothesized relationship between tenure and the adoption of conservation practices depends on the type of conservation practice under study.

The conventional hypothesis is also inadequate in its failure to distinguish between different types of renters. Accordingly we generalize equation (2):

$$(4) \quad \max_{(i)} PV_i = \alpha R_i - \beta C_i + \gamma V_i/(1+r),$$

where $R_i =$ revenues under practice i, $\alpha =$ the farmer's share of revenues, $C_i =$ costs under practice i, and $\beta =$ the farmer's share of costs. This allows us to distinguish three types of farmers according to field tenure status by the parameters α, β, and γ.[4] *Owner-operators* receive all revenues ($\alpha = 1$), bear all costs ($\beta = 1$), and weigh terminal land value fully ($\gamma = 1$) when selecting production practices on a particular field. *Cash-renters* also receive all revenues and bear all costs ($\alpha = \beta = 1$), but weigh future net returns less heavily ($0 \leq \gamma < 1$) than do owner-operators. *Share-renters* receive a share of revenues ($0 < \alpha < 1$), bear a portion of costs ($0 < \beta < 1$), and, like cash-renters, weigh future net returns less heavily ($0 \leq \gamma < 1$) than do owner-operators.

Distinguishing cash-renters and share-renters from owner-operators is important because they have potentially different incentives to adopt conservation practices. On the one hand, the first-order conditions for profit maximization imply that, when choosing input levels, share-renters do not set marginal revenue equal to marginal cost but to β/α times marginal cost, and in general, $\beta \neq \alpha$. On the other hand, the adoption incentive for share-renters can also be affected by differences in shares since β often varies by input. For example, because $\gamma < 1$, both cash renters and share renters would expect to realize less long-term benefits from conservation tillage than would owner-operators. For share renters, however, this effect might be counterbalanced by increased short-term profits if conservation tillage increased the use of a shared input, such as pesticides, while decreasing the use of a renter-provided input, such as machinery or labor. This leads to a refinement of the conventional hypothesis as expressed in the following prediction:

P1: Share-renters and owner-operators are equally likely to adopt conservation tillage, while cash-renters are less likely than owner-operators to adopt conservation tillage.

It is also important to keep in mind the incentives of landlords, although the literature on share tenancy has not always done so sufficiently (Hayami and Otsuka; Miranowski and Cochran). For example, landowners who bear additional input costs when their share-tenants switch to conservation tillage may seek to change the terms of share contracts (α and/or β) or switch to cash leases. Evidence suggests that this may already be occurring (Thompson). Even in the absence of distortions introduced when β is not the same for all inputs, why would a landowner lease his land to a renter when long-term gains from adoption exceed short-term losses,

[4] Individual farmers may operate multiple fields under multiple forms of tenure; we are concerned here with tenure's effect on the operation of each field individually.

and allow soil depletion at a rate higher than he would generate as an owner-operator? To justify rental, the landowner should receive an additional payment in order to compensate for the renter's weaker incentive to preserve the land's value, or require adoption of the conservation practice.

A renter with a contract requiring a conservation practice will be observationally equivalent to a farmer who chooses a conservation practice because it is more profitable. For renters with a conservation requirement in their contract, γ in equations 2–4 would be irrelevant because the renter does not choose between the conservation and conventional practice. If many landowners are requiring that their renters use conservation practices, the model developed in equations 1–4 would not apply, and we would not expect to see any differences in conservation practice adoption between owner-operators and renters.

In practice, the transaction costs of enforcing the use of conservation practices may be higher for some landlords, making it less likely that they will find it profitable to require such practices. For example, Rogers found that 62% of landlords were neither engaged in nor retired from any agricultural activity, and 16% of landlords lived more than 150 miles from their land—factors that may be associated with reduced participation in farm decisionmaking and less awareness of conservation needs and practices.

If it is costly for landowners to require adoption of conservation practices (or to determine and enforce payment of a premium), it seems reasonable to expect that such transaction costs would be inversely related to the extent of the landowner's participation in farm management. Census of Agriculture data show that in addition to sharing input costs and output, landowners participate more actively in management under share leases than they do under cash leases (Rogers). This leads to an additional prediction:

P2: Cash-renters are less likely than owner-operators to adopt medium-term conservation practices, while the effect of share-leasing on adoption of medium-term conservation practices is ambiguous.

Empirical Model

In order to test hypotheses related to the predictions developed above, we assume that there is an unobserved or latent variable, y^*, that generates the observed variable y, which represents a farmer's decision to adopt a conservation practice or not. The latent variable y^* equals $\pi_c - \pi_t + \gamma(\Delta V)$ from equation 3. When y^* is positive, the conservation practice is adopted and $y = 1$ is observed. Otherwise, the conservation practice is not adopted and $y = 0$ is observed. Additionally, $y = 1$ is observed when a renter's contract requires the use of a conservation practice, since then π_t and $\gamma(\Delta V)$ are irrelevant.

For farmer j, the latent variable y_j^* is assumed to be related to observed farmer (and other) characteristics through a structural model as follows (Long):[5]

$$(5)\quad y_j^* = \boldsymbol{\delta}'\mathbf{X_j} + e_j, \qquad (j = 1, \ldots, N)$$

where X_j is a vector of farm, farmer, field, and regional characteristics, δ is a coefficient vector, and e_j is a random disturbance. Then y_j^* is linked to y_j as follows:

$$(6)\qquad y_j = 1 \text{ if } y_j^* > 0, \quad \text{and} \quad y_j = 0 \text{ if } y_j^* \le 0.$$

Farmer j adopts the conservation practice if $y_j^* > 0$. The probability that $y_j = 1$ is then:

$$(7)\qquad \begin{aligned} Pr[y_j = 1] &= Pr[y_j^* > 0] \\ &= Pr[\boldsymbol{\delta}'\mathbf{X_j} + e_j > 0] \\ &= 1 - F(-\boldsymbol{\delta}'\mathbf{X_j}) \\ &= F(\boldsymbol{\delta}'\mathbf{X_j}), \end{aligned}$$

where $Pr[\cdot]$ is a probability function and $F(\cdot)$ is the cumulative distribution function. The exact distribution of F depends on the distribution of the random term e_j. If e_j is distributed as a logistic random variable, then we have a logit statistical model. The empirical model is estimated both for conservation tillage and for medium-term practices.

Data and Methods

The data used in this study were obtained primarily from the 1996 Agricultural Resource

[5] We use the latent variable approach to derive the empirical binary adoption model. However, equivalent binary response models, which are widely used in the study of agricultural technology adoption, can also be derived from the random utility model (Wu and Babcock; Fuglie and Bosch) or from a nonlinear probability model (Long).

Management Study (ARMS) survey administered by the USDA's National Agricultural Statistical Service (NASS). ARMS integrates field-level cropping practices data with farm-level financial and demographic data. Complete records are available for 941 U.S. corn producers in 1996. Since practice and tenure data were collected at the field level, our analysis is restricted to decisions on that particular field (recognizing that farmers may choose different practices for different fields). Additional data were obtained from the NRCS-Oregon State University PRISM project (for temperature and precipitation) and the 1990 Census of Population (for urban proximity).

Because the ARMS data are derived from a complex sampling frame that involves multiple phases of sampling and stratification, including post stratification to adjust for non-response, conventional regression methods yield parameter estimates for which the standard errors are biased. We used a "delete-a-group jackknife" procedure (Kott) with a replication method for variance estimation that computes unbiased standard errors.

Descriptive statistics for the variables selected for analysis are presented in table 1. Survey weights, based on the selection probability of each farm, were provided by NASS and used to expand from the sample to the population of U.S. corn producers in

Table 1. Summary statistics for U.S. corn producers, 1996 ARMS Survey

Variable	Mean	Std. Dev.	Description
Conservation tillage	0.31	0.62	Conservation tillage used in the field (1 = yes, 0 = no)
Med-term practices	0.38	0.93	Contour farming or stripcropping or grassed waterways established in the field (1 = yes, 0 = no)
Farm size	6.12	7.42	Hundreds of acres operated by the farmer
Operator's age	51.25	34.79	Farm operator's age, in years
College education	0.41	0.68	Farm operator had some college education (1 = yes, 0 = no)
Program participation	0.78	1.02	The farm operator participated in government programs if s/he received any government payments (1 = yes, 0 = no)
LRPT farmer	0.26	0.83	Small farm operators who had a main occupation other than farming, were retired, or had gross sales under \$100,000 and total farm assets under \$150,000 (1 = yes, 0 = no)
Corn-soy percent	0.52	0.81	Fraction of the farm planted to corn or soybeans
HEL designation	0.20	0.69	Field classified as "Highly Erodible" by NRCS (1 = yes, 0 = no)
Improved drainage	0.39	0.83	Field has some type of improved drainage (1 = yes, 0 = no)
Urban proximity	1.09	2.29	An index of population weighted by the inverse of distance squared, over 100
Annual precipitation	0.88	0.30	30-year average annual precipitation, in meters
Mean temperature	49.17	15.43	30-year average temperature, in °F
Owner-operator	0.63	0.76	Field is operated by the owner (1 = yes, 0 = no)
Cash-renter	0.20	0.51	Field is operated by a renter under a cash lease (1 = yes, 0 = no)
Share-renter	0.17	0.54	Field is operated by a renter under a share lease (1 = yes, 0 = no)
Plains	0.17	0.72	The farm is located in SD, NE, KS, or TX (1 = yes, 0 = no)
North Central	0.31	0.88	The farm is located in MN, WI, MI, or PA (1 = yes, 0 = no)
Corn Belt	0.45	0.77	The farm is located in IA, MO, IL, IN, or OH (1 = yes, 0 = no)
East	0.07	0.29	The farm is located in KY, NC, or SC (1 = yes, 0 = no)

Sources: ARMS, Census, PRISM.

the sixteen states under study. "Adopters" are farmers who used conservation tillage or one or more "medium-term" conservation practices (contour farming, stripcropping, or grassed waterways) in 1996 on the surveyed field. Conservation tillage was adopted on 31% of sampled fields, while contour farming or stripcropping or grassed waterways was adopted on 38% percent of sampled fields. Sixty-three percent of sampled fields were owner-operated, while 20% were cash-rented and 17% were share-rented.

To isolate the impact of tenure from that of other factors, the effects of farmer, farm, field and regional attributes are also examined. Attributes of the farmer include operator's age, education, government program participation, and farmer type. Younger and more educated farmers are more likely to perceive increased profits from new techniques (Feder and Umali). Operators farming highly erodible land (HEL) must have an approved conservation plan in order to receive certain federal government payments, increasing the likelihood that farmers receiving such payments will realize higher returns from conservation practices than from conventional practices. We hypothesize that limited-resource, retired or part-time (LRPT) farmers are less likely to find conservation practices to be more profitable than conventional practices because they have less time and other resources to devote to farming.

Farm attributes include farm size, the percentage of the farm in corn and soybeans, and proximity to urban areas. Large farm size and area cropped with corn and soybeans have been linked with increased likelihood to adopt conservation tillage because farmers can spread equipment costs over larger areas (Fuglie and Klotz; Gould, Saupe and Klemme; Lee and Stewart; Rahm and Huffman). For medium-term practices, however, the results from earlier studies are not as clear since the same economies of scale are not available. Norris and Batie found that conservation expenditures increased with farm acreage, but others found no significant relationship between cropland acreage and conservation expenditures (Featherstone and Goodwin) or number of conservation practices (Ervin and Ervin). We also included an urban proximity variable to account for the possibility that the farm might be converted to a non-agricultural use in the near future, reducing future benefits from conservation practices and decreasing perceived returns to adoption. This variable is an index of population within fifty miles of the sampled farm, weighted by the inverse of the squared distance from the sampled farm.

Variables that are specific to the field under study are HEL designation, improved drainage, and tenure.[6] By definition, HEL needs conservation to maintain productivity, so conservation practices would likely be more beneficial on HEL than on non-HEL, whether the farmer participates in government programs or not. Improved drainage may indicate inherently wet soils that are less suited to the use of conservation tillage.

Regional effects are captured by average annual temperature and precipitation and by regional dummy variables. Conservation tillage performs less well on cold and wet soils, making adoption less profitable in those areas. In contrast, medium-term practices are more likely to be profitable in areas of high rainfall and potentially higher runoff or erosion. To capture these effects, an Averaged Shifted Histogram (ASH) estimator (Scott and Whittaker) was used to estimate temperature and precipitation at each sampled farm, based on weather data compiled by NRCS and Oregon State University. Four regional dummy variables (Plains, North Central, Corn Belt, and East—see footnote 1) control for regional characteristics such as topography, policy, and extension services.

Estimation and Results

We first test a pair of hypotheses we call the base model: that owner-operators and renters are equally likely to adopt conservation tillage when it offers short-term gains, and that owner-operators are more likely than renters to adopt medium-term practices. In both cases, we test the null hypothesis that $\theta_r = 0$, where θ_r is the coefficient on a dummy variable that is 1 for renters and 0 for owner-operators. Including a dummy variable for tenure implicitly assumes that only the intercept term differs by tenure; slope coefficients are initially assumed constant across tenure classes.

Results of the base model for conservation tillage are presented in the second column in table 2. The coefficient on "Renter"

[6] In some models we included field size as an explanatory variable; however, field size is highly correlated with farm size, and it was not significant in any of the models.

Table 2. Results of the Logit Regression Models for Conservation Tillage, Full Sample (Base) and by Tenure Class, U.S. Corn Producers, 1996

Variable	Base	Owner	Cash-Renter	Share-Renter
Intercept	4.97	4.63	3.25	7.01
	(2.74)	(1.65)	(0.84)	(1.24)
Farm size	0.02	0.01	0.06	0.02
	(2.77)	(0.73)	(0.91)	(0.64)
Operator's age	−0.02	−0.02	−0.02	0.01
	(−2.15)	(−1.93)	(−0.92)	(0.30)
College education	0.63	0.58	0.62	1.05
	(1.76)	(1.27)	(1.38)	(1.93)
Program participation	−0.54	−0.68	0.08	−0.01
	(−1.32)	(−1.50)	(0.07)	(−0.01)
LRPT farmer	−0.92	−0.96	−0.88	−1.14
	(−3.52)	(−2.91)	(−1.33)	(−1.31)
Corn-soy percent	0.75	0.58	1.33	0.63
	(2.29)	(1.18)	(1.33)	(0.56)
HEL designation	0.77	0.40	1.38	1.80
	(3.23)	(1.31)	(3.35)	(1.58)
Improved drainage	−1.14	−1.19	−0.79	−1.50
	(−4.42)	(−2.74)	(−1.29)	(−2.54)
Urban proximity	0.08	0.07	0.27	−0.32
	(0.96)	(0.46)	(1.73)	(−1.09)
Precipitation	−1.01	−2.99	0.36	3.75
	(−0.97)	(−1.59)	(0.11)	(1.15)
Temperature	−0.05	0.01	−0.09	−0.17
	(−1.42)	(0.14)	(−0.97)	(−1.82)
Plains	−1.59	−2.16	−0.56	−2.04
	(−2.00)	(−1.89)	(−0.40)	(−0.76)
North Central	−2.04	−2.01	−1.69	−2.17
	(−3.55)	(−2.26)	(−1.59)	(−0.89)
Corn Belt	−1.50	−1.39	−1.60	−3.20
	(−2.69)	(−1.75)	(−1.66)	(−1.56)
Renter	−0.35			
	(−1.58)			
% correctly predicted	68.5%	64.9%	70.7%	66.9%

Note: (t-statistics in parentheses; critical $t = 2.15$ at 95% and 1.76 at 90% for two-tailed tests)

is negative but not significant. Consistent with past studies, adoption is significantly and positively associated with farm size, education, the proportion of the farm in corn or soybeans, and HEL designation. Older farmers and LRPT farmers were significantly less likely to use conservation tillage, as were those with fields that have improved drainage. Neither climate variable was significant, but farmers in the East were more likely to use conservation tillage than farmers in other regions, probably due to the high rate of adoption in Kentucky (62%), where conservation tillage has a long history of innovation and extension support.

In the base model for medium-term practices (column 2 of table 3), the coefficient on the renter dummy variable is negative and significant. Similar to conservation tillage, operator's age and LRPT farmers are significant and negatively associated with adoption, while HEL designation has a positive and significant impact. However, we also see that the sign on variables other than tenure can vary across conservation practices. For example, farm size and the proportion of the farm in corn or soybeans are negative and significant for medium-term practices, but positive and significant for conservation tillage. This may be because the medium-term practices do not offer the economies of scale offered by conservation tillage. In addition, education and improved drainage are significant for conservation tillage but not for the medium-term practices. Precipitation is positive and significant for the medium-term practices, indicating that such practices occur more frequently where water erosion is a concern. For medium-term practices, the regional dummy variables are not significant.

The nonsignificance of the tenure coefficient in the conservation tillage model, and nonsignificant coefficients on similar tenure variables in other studies, may stem from a failure of the base model to recognize the different incentives facing cash-renters and share-renters. Accordingly, we distinguish cash-renters from share-renters by replacing the base model's Renter dummy with two tenure dummies (cash-rented = 1, otherwise = 0; and share-rented = 1, otherwise = 0). The first modified model tests prediction $P1$, that share-renters and owner-operators are equally likely to adopt conservation tillage, while cash-renters are less likely than owner-operators to adopt conservation tillage. The second modified model tests hypothesis $P2$, that cash-renters are less likely than owner-operators to adopt medium-term conservation practices, while the effect of share-leasing on medium-term conservation practice adoption is ambiguous. In both modified models, the null hypotheses are that $\theta_{cr} = 0$ and $\theta_{sr} = 0$, where θ_{cr} and θ_{sr} are the coefficients on the cash-renter and share-renter dummies, respectively.

Results for this modified model (not shown) are similar to the base model except for the tenure variables. For conservation tillage, coefficients (and t-statistics) on the cash-renter and share-renter variables are −0.54 (−2.05) and −0.12 (−0.42), respectively; cash-renters are significantly less likely than owner-operators to use conservation tillage, while there is no significant difference between owner-operators and share-renters. For medium-term practices, coefficients on the cash-renter and share-renter variables are both negative and significant, at −0.66 (−2.35) and −0.68 (−2.18), respectively, perhaps because expected future returns to such practices are insufficient to outweigh short-term losses. For both types of practices, the results of the statistical tests conform closely to the predictions based on the conceptual model.

It is somewhat surprising that government program participation is not significant in any of these models, but it is difficult to disentangle the interaction of program participation and HEL designation. Most farmers who cultivated highly erodible land in our sample also received payments through USDA programs, meaning they were subject to the conservation compliance provision of the 1985 Farm Act. Because of the high degree of correlation (0.92) between farmers with HEL and program participants with HEL, we are unable to distinguish the effect of the compliance requirement from that of HEL alone. Nevertheless, it seems that farmers are more likely to use conservation practices on HEL fields at least partly to satisfy conservation compliance requirements.

The final test we conducted was to investigate whether slope coefficients (in addition to intercept terms) differ with tenure. We estimated a single extended equation including interaction terms between the two tenure dummies and each of the other independent variables, which is analogous to estimating separate equations for each of the three tenure categories. Based on a likelihood ratio test, we reject the null hypothesis that the slope coefficients are identical across tenure classes, both for conservation tillage and for medium-term practices, meaning that the impact of other factors on adoption depends on the tenure status of the operator. The resulting coefficients are presented in tables 2 and 3 for the conservation tillage and medium-term practices models respectively.

For owner-operators, adoption of conservation tillage is significantly and negatively associated with farmer characteristics, such as age and LRPT status, and with the existence of improved drainage. Owner-operators in the Plains and the North Central region were also less likely to use conservation tillage than those in the East. For cash-renters, only HEL designation is significant. For share-renters, adoption of conservation tillage is influenced positively by education and negatively by improved drainage and temperature. The regional dummies are not significant for cash-renters or share-renters.

Past studies have found farm size to be positively associated with the adoption of conservation tillage, which is consistent with our full-sample results. However, we found that farm size was not significant in explaining adoption of conservation practices when each tenure class was analyzed separately. This may be due to the fact that farm size is larger, on average, for share-renters and cash-renters than it is for owner-operators or the full sample, with means (and standard deviations) of 866 (2073), 722 (1536), 508 (1065), and 612 (742) acres, respectively.

Factors affecting the adoption of medium-term practices also differ with tenure. For

Table 3. Results of the Logit Regression Models for "Medium-Term Practices," Full Sample (Base) and by Tenure Class, U.S. Corn Producers, 1996

Variable	Base	Owner	Cash-Renter	Share-Renter
Intercept	7.35	6.93	10.72	4.01
	(2.98)	(2.22)	(1.85)	(1.13)
Farm size	−0.02	−0.03	−0.02	−0.02
	(−1.91)	(−1.65)	(−0.35)	(−0.61)
Operator's age	−0.03	−0.04	−0.02	−0.02
	(−3.68)	(−3.00)	(−1.18)	(−0.92)
College education	−0.02	0.10	0.13	−0.40
	(−0.08)	(0.22)	(0.21)	(−0.76)
Program participation	−0.04	0.06	−0.84	−0.02
	(−0.15)	(0.17)	(−0.79)	(−0.01)
LRPT farmer	−0.59	−0.67	0.38	−0.87
	(−3.04)	(−1.98)	(0.52)	(−1.00)
Corn-soy percent	−0.56	−0.98	0.27	0.41
	(−1.79)	(−2.34)	(0.28)	(0.36)
HEL designation	2.48	2.73	2.18	2.74
	(10.61)	(8.00)	(3.57)	(3.45)
Improved drainage	−0.06	−0.17	0.18	0.06
	(−0.20)	(−0.39)	(0.36)	(0.13)
Urban proximity	0.13	0.24	0.10	−0.57
	(1.39)	(2.76)	(0.58)	(−2.07)
Precipitation	4.53	3.89	4.27	7.42
	(2.91)	(1.85)	(2.23)	(2.55)
Temperature	−0.22	−0.20	−0.27	−0.24
	(−4.38)	(−3.46)	(−2.14)	(−2.03)
Plains	0.92	1.15	−1.16	1.52
	(0.98)	(0.86)	(−0.48)	(0.76)
North Central	0.51	0.79	−1.52	1.14
	(0.93)	(1.17)	(−1.55)	(0.05)
Corn Belt	0.76	1.03	−0.64	0.89
	(1.62)	(1.41)	(−0.87)	(0.63)
Renter	−0.67			
	(−2.46)			
% correctly predicted	73.4%	71.3%	71.1%	78.5%

Note: (t-statistics in parentheses; critical $t = 2.15$ at 95% and 1.76 at 90% for two-tailed tests)

owner-operators, age, LRPT status, corn-soy percent and temperature are inversely related to adoption, while urban proximity, HEL designation and precipitation are positively associated with adoption. The positive sign on the urban proximity variable is the opposite of the hypothesized effect, perhaps because farmers closer to urban areas have more opportunities for earning off-farm income and thus are more able to invest in conservation structures. For both cash-renters and share-renters, field and climate variables are significant while farmer characteristics are not. HEL designation and precipitation are positively associated with adoption, while temperature is negatively associated with adoption. Urban proximity is negative and significant for share-renters.

A review of tables 2 and 3 shows the importance of HEL designation in the adoption of conservation practices. To further explore the relationships between tenure, HEL, and adoption, we used the coefficients from tables 2 and 3 to estimate probabilities of adoption for each tenure class and practice and then charted how those probabilities change with HEL status (figure 1). At tenure subsample means, all else being equal, probabilities of adoption for owner-operators, cash-renters and share-renters, are roughly twice as high on HEL fields (0.36, 0.47, and 0.58, respectively) as on non-HEL fields (0.27, 0.22, and 0.27). The impact of HEL designation is even more striking for medium-term practices. Adoption probabilities increase threefold or more with HEL designation, from 0.27, 0.22, and 0.11 to 0.85, 0.72, and 0.66.

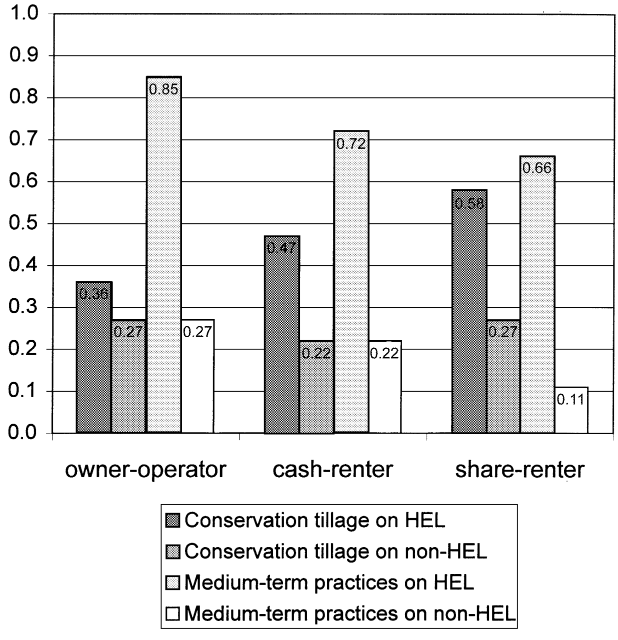

Figure 1. Predicted probability of adoption by practice, tenure, and HEL designation

These results suggest that conservation compliance requirements may be more important to cash-renters and share-renters than to owner-operators when encouraging the use of conservation tillage on HEL. It appears that factors other than HEL and conservation compliance are driving the decisions of owner-operators. However, the presence of HEL is nearly equally important to all tenure classes in predicting the adoption of medium-term practices. Given the close correlation between farmers with HEL and program participants with HEL, this effect may be driven at least in part by the need to meet conservation compliance requirements in order to receive program payments. To the extent that this is the case, such requirements—and the program payments that give them leverage—play a critical role in encouraging adoption.

Discussion

Our results indicate that land tenure is an important factor in farmers' decisions to adopt conservation practices, in ways that are not revealed in conventional analyses. Cash-renters are less likely than owner-operators to use conservation tillage, while share-renters behave much like owner-operators in adopting conservation tillage. Both share-renters and cash-renters are less likely than owner-operators to adopt at least one of the medium-term practices. This suggests that the timing of benefits from conservation practices affects decisions about their adoption, and that landowners are not fully successful in requiring tenants to adopt practices with delayed benefits. The effects of other farmer and land characteristics on adoption also vary with tenure, the most striking being the importance of HEL designation in predicting the adoption of medium-term practices by all tenure types and the adoption of conservation tillage by cash-renters.

These findings have important implications for resource use and quality. Over 40% of U.S. farmland (and about 50% of Corn Belt farmland) is now leased. In addition, a majority of agricultural landowners are neither engaged in nor retired from farming, suggesting that landlords are less involved in the management decisions made by their tenants. Given the adoption probabilities that we estimated for each of the tenure classes, these factors suggest that gains in the adoption of conservation practices in the future may be lower than expected if efforts are not targeted to increasing adoption on rented lands. Also, since HEL designation is so important in explaining conservation decisions, the question arises as to whether renters would continue conservation tillage, and if all farmers would continue using medium-term practices, at the same levels if not subject to conservation compliance provisions. If not, the use of conservation practices could decrease as the leverage provided by conservation compliance falls with declining farm program payments under the 1996 FAIR Act.

While we have modeled the adoption decision as a private choice based on farmers' maximization of private net returns, such findings raise concerns that go beyond private costs and benefits based on changes in soil productivity over time. The adoption of conservation practices also provides public benefits in terms of water quality and other environmental characteristics. To the extent that protecting such benefits requires public policies to influence private decisions, our results indicate the importance of recognizing the role of tenure in the adoption of conservation practices, and of encouraging increased adoption by renters in particular, especially with respect to medium-term practices.

Further research will be necessary to shed light on these and other aspects of the relationship between tenure and the adoption of conservation practices. While our conceptual framework is quite general, our empirical analysis focused on U.S. corn producers. Data limitations currently constrain our ability to generalize to other commodities or countries, but new ARMS data will soon permit similar analyses of U.S. soybean and wheat producers. Additional detail on lease duration, landlord participation, and the date conservation practices were established would allow consideration of longer-term practices and structures such as terraces as well. Our findings also indicate the need for improved understanding of the decision by landowners and farmers to acquire or lease land in the first place, of the extent to which landlords can require tenants to adopt particular production or conservation practices, and thus of the ways in which tenure patterns themselves evolve over time.

[Received August 1998;
accepted December 1999.]

References

Belknap, J., and W.E. Saupe. "Farm Family Resources and the Adoption of No-Plow Tillage in Southwestern Wisconsin." *N. C. J. Agr. Econ.* 10(January 1988):13–23.

Bills, N.L. *Cropland Rental and Soil Conservation in the United States*. Washington DC: U.S. Department of Agriculture, ERS Agr. Econ. Rep. 529, March 1985.

Cheung, S. *The Theory of Share Tenancy*. Chicago: University of Chicago Press, 1969.

Day, J.C., C.L. Sandretto, W.D. McBride and V.E. Breneman. "Conservation Tillage in U.S. Corn Production: An Economic Appraisal." Paper presented at the AAEA meeting, Salt Lake City UT, 2–5 August 1998.

Ely, R.T., and G.S. Wehrwein. *Land Economics*. New York: Macmillan Co., 1940.

Esseks, J.D., and S.E. Kraft. "The Use of Conservation Practices by Part-Owner Operators." *Land Use Policy* 6(January 1989):31–41.

Ervin, C.A., and D.E. Ervin. "Factors Affecting the Use of Soil Conservation Practices: Hypotheses, Evidence and Policy Implications." *Land Econ*. 58(August 1982):277–91.

Featherstone, A.M., and B.K. Goodwin. "Factors Influencing a Farmer's Decision to Invest in Long-Term Conservation Improvements." *Land Econ*. 69(February 1993):67–81.

Feder, G., and D.L. Umali. "The Adoption of Agricultural Innovations: A Review." *Technological Forecasting and Social Change* 43(May/June 1993):215–39.

Fuglie, K.O., and D.J. Bosch. "Economic and Environmental Implications of Soil Nitrogen Testing: A Switching Regression Analysis." *Amer. J. Agr. Econ*. 77(November 1995):891–900.

Fuglie, K.O., and C.A. Klotz. "Adoption of Conservation Tillage in the Lower Susquehanna Basin." Paper presented at the NAREA meeting, Newark DE, 27–29 June 1994.

Gould, B.W., W.E. Saupe, and R.M. Klemme. "Conservation Tillage: The Role of Farm and Operator Characteristics and the Perception of Soil Erosion." *Land Econ*. 65(May 1989):167–82.

Hayami, Y., and K. Otsuka. *The Economics of Contract Choice*. Oxford: Clarendon, Press, 1993.

Heimlich, R.E. "Landownership and the Adoption of Minimum Tillage: Comment." *Amer. J. Agr. Econ*. 67(August 1985):679–381.

Hinman, H.R., S.G. Mohasci, and D.L. Young. "Impact of Tenure Status on Economic Incentives for Conservation Tillage." *J. Soil and Water Conserv*. 38(May–June 1983):287–90.

Klemme, R.M. "A Stochastic Dominance Comparison of Reduced Tillage Systems in Corn and Soybean Production under Risk." *Amer. J. Agr. Econ*. 67(August 1985):550–57.

Kott, P.S. *Using the Delete-A-Group Jackknife Variance Estimator in NASS Surveys*. Washington

DC: U.S. Department of Agriculture, NASS Rep. RD–98–01, 1998.

Lee, L.K. "The Impact of Landownership Factors on Soil Conservation." *Amer. J. Agr. Econ*. 62(December 1980):1070–71.

Lee, L.K., and W.H. Stewart. "Landownership and the Adoption of Minimum Tillage." *Amer. J. Agr. Econ*. 65(May 1983):256–64.

Long, J.S. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, CA: Sage Publications Inc., 1997.

Lynne, G.D., J.S. Shonkwiler, and L.R. Rola. "Attitudes and Farmer Conservation Behavior." *Amer. J. Agr. Econ*. 70(February 1988):12–9.

McConnell, K.E. "An Economic Model of Soil Conservation." *Amer. J. Agr. Econ*. 65(February 1983):83–9.

Miranowski, J., and M. Cochran. "Economics of Land in Agriculture." *Agricultural and Environmental Resource Economics*. G.A. Carlson, D. Zilberman and J.A. Miranowski, eds., pp. 392–440. New York: Oxford University Press, 1993.

Nielsen, E.G., J.A. Miranowski, and M.J. Morehart. *Investments in Soil Conservation and Land Improvements: Factors Explaining Farmers' Decisions*. Washington DC: U.S. Department of Agriculture, ERS Agr. Econ. Rep. 601, January 1989.

Norris, P.E., and S.S. Batie. "Virginia Farmers' Soil Conservation Decisions: An Application of Tobit Analysis." *S. J. Agr. Econ*. 19(July 1987):79–90.

Rahm, M.R. and W.E. Huffman. "The Adoption of Reduced Tillage: The Role of Human Capital and Other Variables." *Amer. J. Agr. Econ*. 66(November 1984):405–13.

Ribaudo, M.O., and R.A. Shoemaker. "The Effect of Feedgrain Program Participation on Chemical Use." *Agric. Resource Econ. Rev*. 24(October 1995):211–20.

Robison, L.J., and P.J. Barry. *The Competitive Firm's Response to Risk*. New York: Macmillan Co., 1987.

Rogers, D. *Leasing Farmland in the United States*. Washington DC: U.S. Department of Agriculture, ERS Rep. AGES–9159, 1991.

Scott, D.W., and G. Whittaker. "Multivariate Applications of the ASH in Regression." *Communications in Statistics* 25(November 1996): 1521–30.

Stiglitz, J.E. "Incentives and Risk Sharing in Sharecropping." *Rev. Econ. Studies* 41(April 1974):219–55.

Thompson, M. "No-till Reshapes Land Leases." *Farm J.* (September 1994):11–12.

Wu, J., and B.A. Babcock. "The Choice of Tillage, Rotation, and Soil Testing Practices: Economic and Environmental Implications." *Amer. J. Agr. Econ*. 80(August 1998):494–511.

Young, C.E., and J.S. Shortle. "Investments in Soil Conservation Structures: The Role of Operator and Operation Characteristics." *Agr. Econ. Res*. 36(Spring 1984):10–15.